Amsat-DL and the Voyager-1 receiving experiment
with the Bochum 20m dish (IUZ)

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AMSAT-DL

Amsat designs construct and maintain satellites in elliptical orbit for radio amateurs.
Amsat does science space research and makes flying radio communication systems where the amateur radio participation is a key for global observations.
It makes the results of these research available trough publications.

Projects

Amsat launched its first satellite in 1961 (Oscar 1) Amsat-DL started with high flying balloons (Artob) in the 60's Since then several satellites have been launched by Amsat-DL: Oscar-7 – Uosat Oscar 9 (BCR) Oscar 10, 13, 21 and Oscar 40

Currently the P3E elliptical orbit satellite and P5A Mars orbiting satellite are under construction.

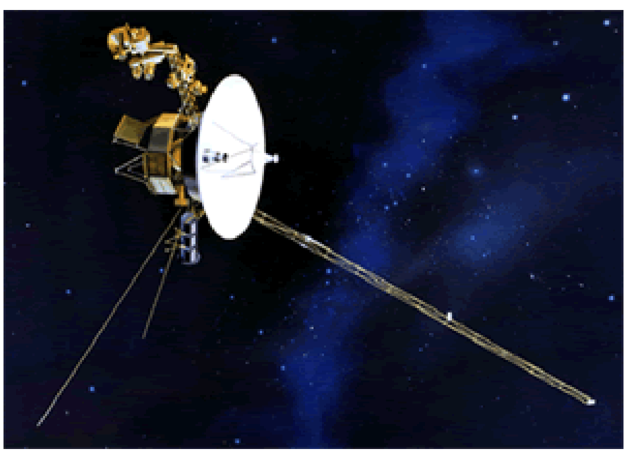
Ground station for the Mars P5A mission

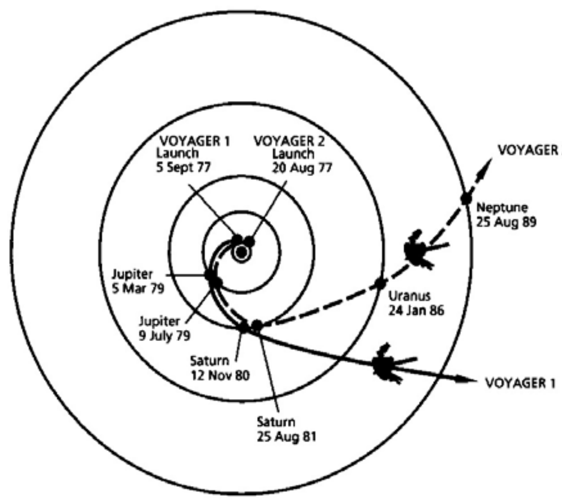
Amsat-DL prepares for the Mars P5A mission with the construction of one or more ground stations capable of commanding the P5A mission to Mars.
The Bochum 20m dish is the key ground station and is since 2001 being refurbished for tracking the P5A and other missions.

As part of the evaluation and to gather experience the ground station is tracking deep space missions on a regular basis. Venus reflection tests have been done in 2004 and early 2006.
The Voyager-1 experiment was done in 2006.
It also takes part in EME tests to support amateur radio communication experiments.
Recently polarization have been conducted on 10 GHz.
During these operations gradually station improvements are defined to prepare the ground station for the very demanding P5A operations.

The Voyager-1 receiving experiment

Voyager-1 was launched in 1977 (29 years ago) and still operates as the most distinct man made object in space. The satellite is powered by a thermal nuclear device and transmits into the 8.4 GHz Deep Space frequency allocation. It is still tracked on a regular basis with 72m deep space network antennas.
The beacon transmits with 15 or 18 W in a non-coherent transponder mode. The telemetrie (160 baud) contains temperatures and magnetic values. The space craft is at the outer edge of our solar system and at 14.7 billion km at the time of the test. Due to the system temperature changes the frequency changes by some 2 kHz from the nominal transmit frequency.





The stability of the equipment needs to be better then 1 Hz at 8.4 GHz to

Requirements for receiving Voyager-1: (courtesy James Miller G3RUH)

Launched: 1977 Sep 05

TX power is quoted as 12W or 21.3W. Since the s/c is 27 years old, the power decreased to 10W/18W (according to JPL). Residual carrier is in use, and the

modulation index setting varies. It is 60° at 160 bps, the normal housekeeping rate. Thus use -6 dB (info from JPL)...

Transmitter power = 18 Watts (RF) 12 W lo power
Antenna 3.66m dish = 48 dBic (from JPL docs)

Estimate of e.i.r.p.

X power 12.6 dBW High power mode, low data rate
S/C Antenna gain 48 dB At 8.4 GHz

TX e.i.r.p Pt 60.6 dBW
Residual carrier -6 dB MI=60°

Carrier e.i.r.p. Pc 54.6 dBW = 288 kW

CNR Calculation
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At range R = 14.702*10^12 m: (2006 Apr 01)

Received flux F = Pc/(4 pi R^2)
= 1.05E-22 W/m^2

Received power Pr = F A W For A = 160 m^2 (Bochum antenna)
= 1.68E-20 W

RX noise power Pn = k Tr B W For Tr=175K and B=1 Hz
= 2.42E-21 W

CNR CNR = Pr/Pn
= 6.93

= 8.43 dB-Hz (SNR in B = 1 Hz)
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Note: X-band TWT-1 is continuously on, and uses LHCP (not RH).

Actually received 2006 Mar 31 at CNR = 7.8 dB-Hz +/-0.18 dB
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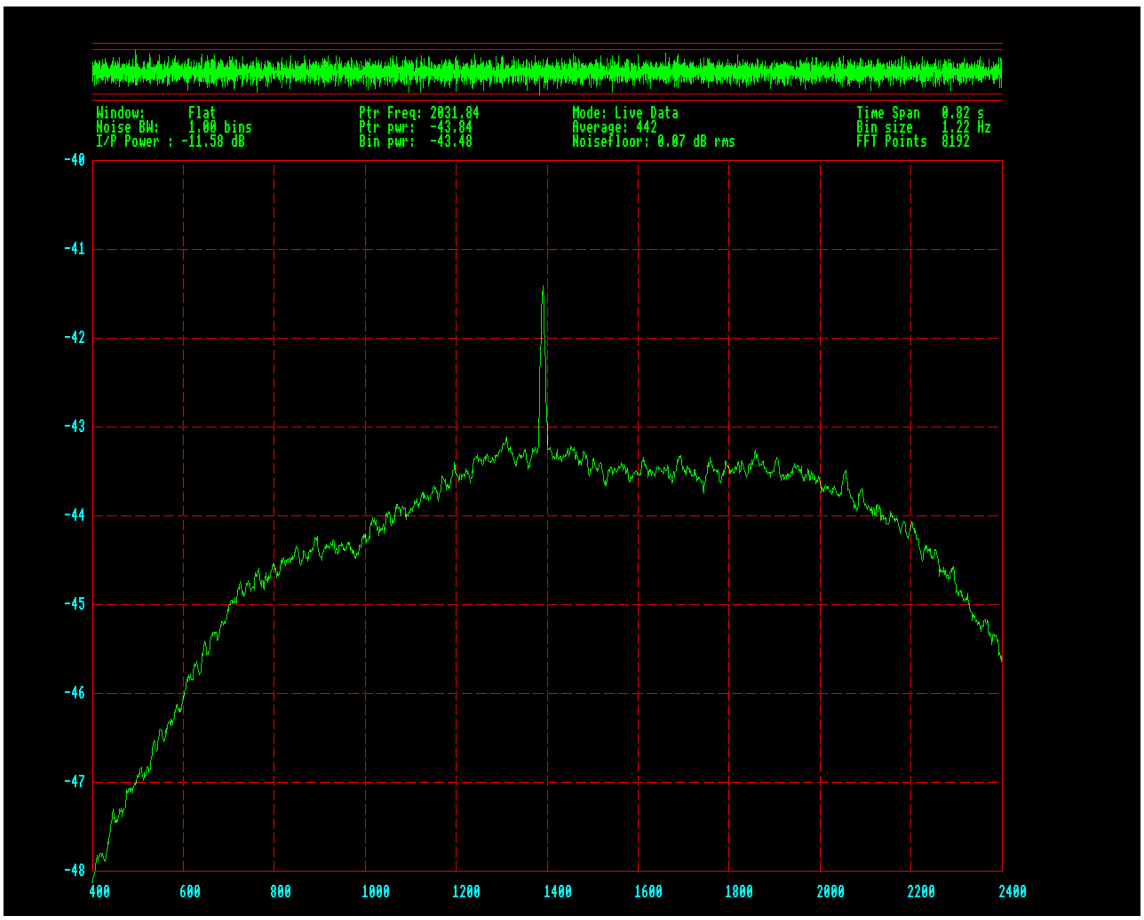
The equipment

In order to receive this kind of signal we need to use equipment with good frequency stability and make use of computer DSP techniques.
An FFT program that displays the passband of a normal SSB channel (about 2 kHz) was used. The accumulated “bins” being in the order of 1 Hz. In essence the signal is a drifting carrier step tuned by the IF receiver. I refer to more detailed description of the art of the DSP technique described by James Miller G3RUH. (ref 1)

The equipment in Bochum uses a converter (Kuhne Electronics) to convert the 8.4 GHz to 1270 MHz IF. The IF receiver is an FT736 Yaesu that has been frequency adjusted and verified for short term stability within a few Hz at 1270 MHz. The Doppler frequency change (mainly earth rotation) is controlled by a separate tracking program. The FT736 has a frequency step of 10 Hz so the stability of the equipment needs to be better then 1 Hz at 8.4 GHz to view the signal within the 10 Hz step changes of the FT736.

The LO of the converter was locked to 10 MHz rubidium standard oscillator that was frequency adjusted with the aid of a GPS reference oscillator. The frequency stability was better then 10E-11 .

Tracking of the Bochum 20 m dish is done by a separate computer that keeps the dish within 0.01 deg on the target. Time is GPS controlled.



X-band Deep Space Network frequencies and satellites

DSN ch no.	DL frequency{MHz]
5	8402.777780
6	8404.135803

7 8405.493826
8 8406.851853 M01O Mars Odyssey
9 8408.209876 ULYS Ulysses
10 8409.567903
11 8410.925927
12 8412.283950
13 8413.641977
14 8415.000000
15 8416.358023
16 8417.716050 MGS Mars Global Surv.
17 8419.074073 VEX Venus Express
18 8420.432097 MEX Mars Express
19 8421.790124 Rosetta
20 8423.148147 MGS Mars Global Surv.
21 8424.506174
22 8425.864197
23 8427.222220 CAS Cassini non coh.
24 8428.580248
25 8429.938271 CAS Cassini coherent
26 8431.296294
27 8432.654321 Messenger ?
28 8434.012344
29 8435.370371 MER Spirit Opport.
30 8436.728393
31 8438.086418 NH New Horizons
32 8439.444445 MRO Mars Recog. Orbit.
33 8440.802468

MRO also at 32069.888889 MHz
Voyager 1 8420.428520 MHz
New Horizons 8437.8947 MHz ?

References
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(1) Empfang von Voyager 1 mit der 20 m Antenne des IUZ Bochum , James Miller G3RUH
Achim Volhardt DH2VA/HB9DUN Amsat-DL journal nr 2. Jg 33 Juni/August 2006.